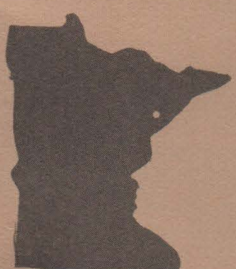
FOREST INSECT AND DISEASE MANAGEMENT / evaluation report

S-23-76

EVALUATION OF 1 POUND AND 1/2 POUND SEVIN 4 OIL APPLICATIONS FOR SPRUCE BUDWORM CONTROL IN MINNESOTA, 1975



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Summary

Two dosages and application rates of Sevin 4 Oil were used for spruce budworm suppression in Minnesota in 1975. Ten days after spraying, the 1 lb/40 fl oz/acre rate had reduced the budworm larval population 96 percent and the 1/2 lb/20 fl oz/acre application had reduced the population 92 percent. Less than 1/2 larva per 15-inch branch survived the treatments on most spray blocks. There were no significant differences in larval mortality or survival between treatments. Both are equally effective. Foliage protection could not be determined because defoliation was essentially completed before spraying.

Carbaryl residues were detected in water and soil for one month after treatment and for two months on fir foliage.

Drift of some aquatic insects (Simuliids) increased for about two hours after spraying. Other aquatic insect drift did not increase significantly. Fish, birds and small mammals were not adversely effected.

The 40 fl oz/acre application rate produced larger drops and greater volume, but nearly the same drop coverage density as than the 20 fl oz/acre application rate. Spruce budworm control effectiveness seems to be related to the number of drops per unit area and not to the volume of spray deposited.

Introduction

The Spruce budworm, *Choristoneura fumiferana* (Clem.), is a major insect pest of balsam fir and spruce in North American forests. Chemical suppression is often required to prevent excessive timber mortality. Sevin 4 Oil[1] is registered for spruce budworm control in the northeastern United States by U.S. Environmental Protection Agency for spruce budworm control to be applied at the rate of one qt/acre (1 lb ai/acre). Since the spruce budworm is also a major pest in the Lake States, a pilot control project was designed to evaluate the recommended rate in Minnesota and to determine the effectiveness of a reduced application rate.

The pilot project was a cooperative effort between the Minnesota Department of Natural Resources (DNR), University of Minnesota (UM), U.S. Fish and Wildlife Service and the U.S. Forest Service.

Objectives

The pilot control project was designed to: (1) determine the effectiveness of 1 lb ai/acre and 1/2 lb ai/acre applications of Sevin 4 Oil in reducing spruce budworm populations and preserving foliage, and (2) determine the persistance of carbaryl in soil, water, and balsam fir foliage and (3) determine the effects of the insecticide on aquatic insects, fish and wildlife.

Materials and Methods

Insecticide

Sevin 4 Oil®, an emulsion containing four lbs carbaryl insecticide per gallon, was diluted 25 percent with No. 2 fuel oil and applied at the rate of 40 fl oz (1 lb ai) and 20 fl oz (1/2 lb ai) per acre. Rhodamine B, fluorescent oil soluable red dye was added at the rate of 0.82 lb/100 gallons of final spray mixture to improve the visibility of spray deposit on sample cards.

Application

The insecticide was sprayed from a Bell 47 helicopter equipped with two Beecomist 350 rotary spray nozzles with 100-micron sleeves. The aircraft, flown at 45 mi/h airspeed and 100-ft swath width, was calibrated to release 2.84 g/min and 1.42 g/min to give 40 fl oz/acre and 20 fl oz/acre coverage.

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[1]Use of trade, firm or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

The 20 fl oz rate was applied June 16, 1975, between 1900 and 2100 hours. The 40 fl oz rate was applied the following morning between 0830 and 1030 hours. The evening was calm, the temperature decreased from 68°F to 58°F and the relative humidity increased from 60 percent to 95 percent. Morning spraying was delayed because of heavy fog. At the start, dew was on the foliage but not dripping, the wind was less than three mi/h and the temperature was 50°F. At the conclusion, the relative humidity was 95 percent, the temperature 58°F and wind at about six mi/h, gusting to 15 mi/h. About 0.5 inch of rain fell eight hours later.

Spruce budworm larval development was advanced because spraying had been delayed by bad weather. Four days before spraying about half of the larvae in the southern blocks and a quarter of those in the northern blocks were in the sixth instar but no pupae were found. Four days after spraying, about 20 percent of surviving population in the south blocks had pupated. I suggest that some of the larvae in the southern blocks were non-feeding prepupae at the time of spraying.

Projection Location and Design

The spray blocks were about 15 miles north of Duluth, Minnesota. The area is flat lowland where balsam fir grows in mixture with aspen, spruce and pines. The spray blocks were about 200 acres each, of which one quarter to one half was balsam fir type. Small, intermittent creeks, draining the lowlands of spring snow melt, were present in most of the blocks.

Two spray blocks located in the southern area were sprayed with each of the application rates. A single block located about six miles northeast was treated with the 40 fl oz rate. About 10 miles north of the first area were three blocks—two of which were treated with 20 fl oz rate and one block with 40 fl oz rate. A check block was located within a mile of each spray area. The check block in the southern area was accidentally sprayed during calibration and was deleted from the data analysis.

Ten sample clusters were systematically located within each spray block. However, three clusters in the corner of the 40 fl oz rate block in the north area were not sprayed. Similarly, one cluster in the northern 20 fl oz rate block was not sprayed. These four clusters were deleted from the control efficacy evaluation. Each sample cluster consisted of five dominant and codominant balsam firs. In the check blocks, the number of trees per cluster was increased to 10. The reason for reduced number of samples was that a low population variability was expected in the unsprayed areas.

Spruce Budworm Population Estimates

The density of larval populations was determined from three 15-inch sample twigs collected from the midcrown of the trees four days before spraying and four and 10 days after spraying. In the check blocks, an additional collection was made on the spray day. Samples from each tree were placed in paper bags, marked, and delivered to the Eveleth Nursery where they were examined for larvae. The numbers of larvae per twig were recorded by instars, and defoliation estimates were made by age class of foliage—buds, current needles, previous years needles and older foliage.

Residue Analysis

Samples were collected only in the 20 fl oz treatment block from a small creek tributary, a one-acre beaver pond, humus, subhumus soil at six inches and balsam fir foliage. Water was samples for both surface water and bottom mud. Soil and foliage samples consisted of three samples from each of three sampling areas. Collections were made one week before spraying and 1, 4, 10, 30 and 60 days after spraying. In addition, water samples were collected 14 and 20 hours after spraying. The samples were delivered to the laboratory on the day of collection and frozen until the analysis was made.

Soil and bottom mud samples were air-dried, high speed blended and filtrated. Carbaryl was extracted with methylene chloride. After evaporation, a color reagent, p-nitrobenzene diazonium fluoborate and glacial acetic acid was added for colorimetric determination at 475 mu.[2]

Balsam fir foliage and humus samples were analyzed with a modified method substituting chloroform for methylene chloride.[2] Samples were analyzed until 1ppm or less carbaryl was found in two successive collections.

Aquatic Insect Evaluation

Aquatic insect drift collections, bottom fauna measurements and rearing of selected insects were done in the intermittent stream, also used for carbaryl residue evaluation. Before spraying, the stream was about two feet wide and six inches deep. It ran through a culvert under the gravel logging road. The upper end of the stream has poorly defined banks, but near the sampling area they were more obvious. The two drift nets, six inches X 12 inches at the mouth and 48 inches long, were placed side by side in the stream. The stream discharge about 10 days before spraying was 0.22 ft^3/s. Frequent rainfall caused the discharge to increase five fold by the time of spraying. The increased runoff caused the stream to leave its banks and flood large areas. A week later the discharge decreased to 0.55 ft^3/s

Collections of aquatic insects were made at about two hour intervals, but more frequently immediately after spraying. Sampling usually was continuous for a 24-hour period.

Stream bottom samples were taken from four locations in the stream. Each sample was collected from about a 0.75 ft^2 area with a dredge. Samples were collected about 10 days before and seven days after spraying.

Odonata nymphs and Trichroptera larvae were collected four days before spraying and placed separately in wire cages filled with gravel and detritus. One cage of each insect species was placed in the sprayed stream, and in an unsprayed stream about eight miles away. The cages were reexamined a week after spraying.

Bird and Mammal Surveys

Inspections along predetermined paths were made to detect abnormal behavior of the animals. The small creeks within and adjoining the spray blocks were void of game fish. A few minnows were collected as part of aquatic insect drift sampling.

Spray Coverage

White Kromekote spray deposit cards were set out in the midcrown of sample trees at the rate of three cards per cluster. A card holder was designed that could be raised like a flag on a pole on a fish line drapped over a mid-crown branch. Spray cards were set out in the afternoon before spraying and collected before noon the following day. The spray drops were measured and counted by the Experimental Systems Division, U.S. Army, Dugway Proving Grounds, Utah.

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[2]Official method in Jour. Assoc. Official Analyt. Chemists. 1964. 47(1):189-91

[3]Union Carbide Corp. 1974. June Rept. A method for the determination of residues of carbaryl on plant foliage.

Results and Discussion

Effects of Spraying on Spruce Budworm

Mortality

Four days after spraying, spruce budworm populations had declined an average of 87.3 percent in the 1/2 lb/acre spray block, 88.6 percent in the 1 lb/acre spray blocks and 34.0 percent in unsprayed checks (Table 1). Ten days after spraying the average population decline was 92.5 percent, 96.3 percent and 60.2 percent, respectively, for the treatments. The larval mortality between the sprayed and unsprayed blocks was significant (at 95 percent level of confidence), but the difference between 1/2 lb/acre and 1 lb/acre rates was not.[4] The population decline resulting from the three treatments is shown in Figure 1. The natural mortality that occurred between four days before spraying and the spray day was based on samples in the untreated checks only, but is assumed to be the same for all the blocks for the above calculations. The large population decrease in the checks is probably the result of the high larval populations competing for a rapidly decreasing food supply. It is interesting to note that the final population density in the sprayed blocks was 93 percent less than in unsprayed checks. This percentage is similar to the percentage of population reduction in sprayed blocks between pre- and postspray counts.

Survival

The percentage of larval mortality is a widely used indicator of spraying effectiveness, but, the success of the treatment depends more on the budworm population surviving the treatment. In the 1 lb/acre treatment blocks, an average of 1.42 larvae per 15-inch twig were alive four days after spraying, but only 0.44 larva survived to the tenth day. In the 1/2 lb/acre blocks an average of 0.75 larva per twig was alive four days after and 0.48 larva per twig survived 10 days after treatment (Table 2). Population adjustments were necessary during analysis to account for the non-feeding and insecticide-resistant pre-pupae present in the population at the time of spraying. In the check blocks, four days after treatment there were 10.34 larvae per twig. This population decreased to 5.98 larvae/twig 10 days after treatment. Despite the different population levels before spraying, the two spray treatments resulted in similiar population density 20 days after treatment (Figure 2). The differences in surviving populations between sprayed and unsprayed blocks are significant at 95 percent level of confidence (Scheffe Technique), but are not significant between the two spray treatments.

Foliage Protection

One of the prime objectives for spraying spruce budworm is immediate foliage protection to prevent tree mortality. Because of unexpected delays in this pilot control project, defoliation was nearly complete by the time of spraying. Since the number of larvae per twig determines the amount of defoliation expected, we can make some assumptions about foliage protection.

Nearly complete defoliation of balsam fir causes tree mortality. In the project area the previous defoliation was about 50 percent. If we assume that a surviving population, in the fourth and later instars, of five or more larvae per 15-inch twig will cause complete defoliation, we can examine the data to determine if the spraying was successful. None of the 56 sample clusters sprayed had an average of five or more larvae per twig, but all of the unsprayed check clusters had more than five larvae per twig (Figure 3). In fact, 15 percent of clusters had no surviving larvae and 70 percent had an average of one or less larva per twig. Only five percent of the clusters had an average of three larvae per twig, which might result in significant defoliation.

[4]Newman-Keuls Test, Hartley's modification, using arc-sine transformation (Snedecor, G.W. and W.G. Cochran. 1956. Statistical Methods. 5th Ed., p. 253).

Spray Coverage and Budworm Mortality

The 40 fl oz/acre application rate resulted in higher deposits on the spray cards for all the mass related values—diameter of drops, mass weight, and volume—than the 20 fl oz/acre application rate (significant at 99 percent, Student's t test) (Table 3). However, the total number of drops/m^2 and the number of drops/m^2 in the smaller size classes (under 112 microns) were not different between the two application rates (not significant at 95 percent, Student's t test). Apparently, the higher application rate produced more of the large drops, and therefore volume, but did not improve coverage. Further tests are needed on the operation for the Beecomist nozzles, which were supposed to produce similar drop spectra for both application rates.

No statistical correlation was found between the mass median diameter, mass mean diameter, number median diameter, number mean volume and number mass volume and spruce budworm mortality, or survival (R^2 less than 0.1). Analysis was based on comparisons of spray cards and spruce budworm populations by individual trees as well as by clusters.

Similarily, no correlation was found between spray deposit density (drops/m^2) and budworm mortality. Even the number of larvae surviving the treatment at first did not appear to be correlated with the spray deposit. The correlation statistics were greatly influenced by the low survival in most samples—25 percent of trees at four days and 47 percent at 10 days after spraying had no survivors. When the samples were grouped by number of larvae surviving and then plotted against the average number of drops/cm^2 for that group, a relationship becomes apparent (Figure 4). High survival is possible when the spray deposit is less than four drops/cm^2, quite variable at four and five drops/cm^2, and 0 survival is approached with six or more drops/cm^2.

Another relationship was found between the drop size and budworm survival. The total number of drops and the number of small drops (under 112 microns) appears to be related to the percentage of trees with less than 0.33 larva per twig (Figure 5). The same relationship does not hold for the larger size drops.

The large drops do not seem to be more effective. Thus, future tests should concentrate on increasing the deposit of smaller droplets without increasing the volume of insecticide used.

Carbaryl Residues

In the area sprayed with the 20 fl oz/acre rate (1/2 lb/ai/acre), the highest residues were found in a beaver pond (3.0 ppm), and balsam foliage (2.74 ppm) the first day after application. About 10 days after spraying the residues decreased to 1.00 ppm and 1.44 ppm, respectively. Residues were below 1 ppm 30 days after spraying. Residues in soil at 6-inches, humus, running water and bottom mud in the stream and beaver pond reached about one ppm or less the first day after spraying and were undetectable within a month.

Adverse Effects on Aquatic Insects

Aquatic insect drift during a 24-hour period was about one million per cubic meter of water per second 10 days before spraying (Table 4). On the day of spraying the drift had declined to 524,000/m^3/s and by a week later it was down to 46,000/m^3/s. If spraying had a serious effect, the insect drift should have increased during the spray period. Instead, the drift of all insect groups declined. Hourly collection data showed a drift peak of Simuliidae for about two hours after spraying, followed by a decline to the normal level. Chironomidae, the second largest insect group drifting, did not show increased drift rates after spraying (Figure 6).

The drift sampling method for evaluating adverse effects on aquatic insects seems to be weak. Insect emergence, changes of water levels as a result of rain, and lack of knowledge about the biology of drifting insects make quantitative evaluation difficult.

Most of the insects placed in the rearing cages in the sprayed and unsprayed creeks survived. The largest discrepancy was caused by missing insects the reason for which was not found. Stream bottom samples were practically devoid of insects and poorly represented by other groups of animals. Only 17 organisms were found in four prespray samples, and nine in the postspray samples.

Conclusions

Effectiveness of Spraying

Both application rates, 1 lb carbaryl in 40 fl oz/acre and 1/2 lb carbaryl in 20 fl oz/acre, provided good spruce budworm larval mortality—96.3 percent and 92.5 percent, respectively—10 days after treatment. The surviving populations were low, 0.44 larva per 15-inch twig and 0.48 larva per 15-inch twig for the respective treatments. About 85 percent of the trees had one or less larva per 15-inch twig surviving 10 days after treatment. There was no significant difference in budworm mortality or survival between the two application rates. Use of the lower application rate should be considered on future budworm suppression projects in Minnesota.

Residues of Carbaryl

In the area treated with 0.5 lb ai carbaryl in 20 fl oz/acre, the highest residue, 3.0 ppm, was found in pond water the first day after spraying. All the residues in soil, humus, water and foliage were negligible 30 days after treatment (<1ppm).

Adverse Effects on Other Organisms

No significant adverse effects were observed in birds, small mammals, fish and most aquatic insects. For about two hours after spraying, the drift rate of Simuliids increased. Other aquatic insects were apparently not affected.

Acknowledgments

The author expresses appreciation to the many individuals and groups for their assistance in the successful completion of the project. Minnesota DNR provided land for testing and staff for aquatic drift evaluation. Mr. G. Hecht and his staff of the DNR assisted in the field work. Dr. E. Cook and Dr. L. Cutkomp, Department of Entomology, Univ. of Minn., identified drift specimens and analyzed carbaryl residues, respectively. Dr. J. Elder, U.S. Fish and Wildlife Service spent many extra hours evaluating adverse effects on wildlife. Mr. J. Barry, Army Proving Grounds at Dugway, Utah provided spray card analysis (now with the Forest Service). Mr. J. Allen, Union Carbide Chem. Co. assisted in calibration of aircraft and chemical mixing. Technical assistance was provided by Dr. H. Batzer, Entomologist, and Mr. P. Laidly, Statistician of the North Central Forest Experiment Station.

Pesticide Precautionary Statement

This publication reports pilot control project results involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for disposal of surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

Table 1. — *Spruce budworm larval mortality four and ten days after spraying with Sevin 4 Oil in Minnesota, 1975*

(in percent)

Treatment	Four days Mean[a]	Four days SE	Ten days Mean[a]	Ten days SE
½ lb/acre	87.3[a]	1.29	92.5[a]	4.16
1 lb/acre	88.6[a]	2.99	96.3[a]	1.53
Check	34.0[b]	27.2	60.2[b]	19.30

[a]Means followed by unlike letter values are significantly different at 95 percent confidence level (Arc sine transformation).

Table 2. — *Effect of treatment on spruce budworm population density*

(number of budworm/15-inch twig)

Treatment	Prespray Survey Mean no.	Prespray Survey SE	Postspray Surveys Four days Mean no.[a]	Four days SE	Ten days Mean no.[a]	Ten days SE
½ lb/acre	4.83	1.39	0.65[a]	0.25	0.48[a]	0.35
1 lb/acre	12.91	1.28	1.42[a]	0.36	0.44[a]	0.15
Check	19.36	9.00	10.34[b]	0.68	5.98[b]	0.15

[a]Means followed by unlike letters are significantly different at 95 percent level of confidence (Scheffe Technique).

Table 3. — *Sevin 4 Oil spray deposit data*

Drop Size and Coverage	Application rate per acre 20 fl oz	Application rate per acre 40 fl oz
Drop Sizes		
Mass median, microns	128	203
Mass mean, microns	69	106
Number median, microns	29	47
Number mean, microns	39	62
Percent under 112 microns	88	76
Percent 112 microns and larger	12	24
Coverage		
Milligrams per m^2	7	29
oz per acre	1	4
drops per cm^2	4.46	5.52

Table 4. —*Numbers of insects drifting past a point in the stream before and after spraying.*

(1000 insects/m³/s)

Insect Group	Prespray June 4-5	1st Postspray June 16-17[a]	2nd Postspray June 23-24
Diptera			
Simuliidae	454	378	8
Chironomidae	177	106	27
Other	26	13	4
Ephemeroptera	265	11	<1
Odonata	61	2	<1
Trichoptera	21	2	2
Plecoptera	6	2	1
Coleoptera	14	10	4
Total	1,024	524	46

[a]Stream was sprayed at 2030 hours, June 16, but sampling was done from 1600 hours to following day at noon.

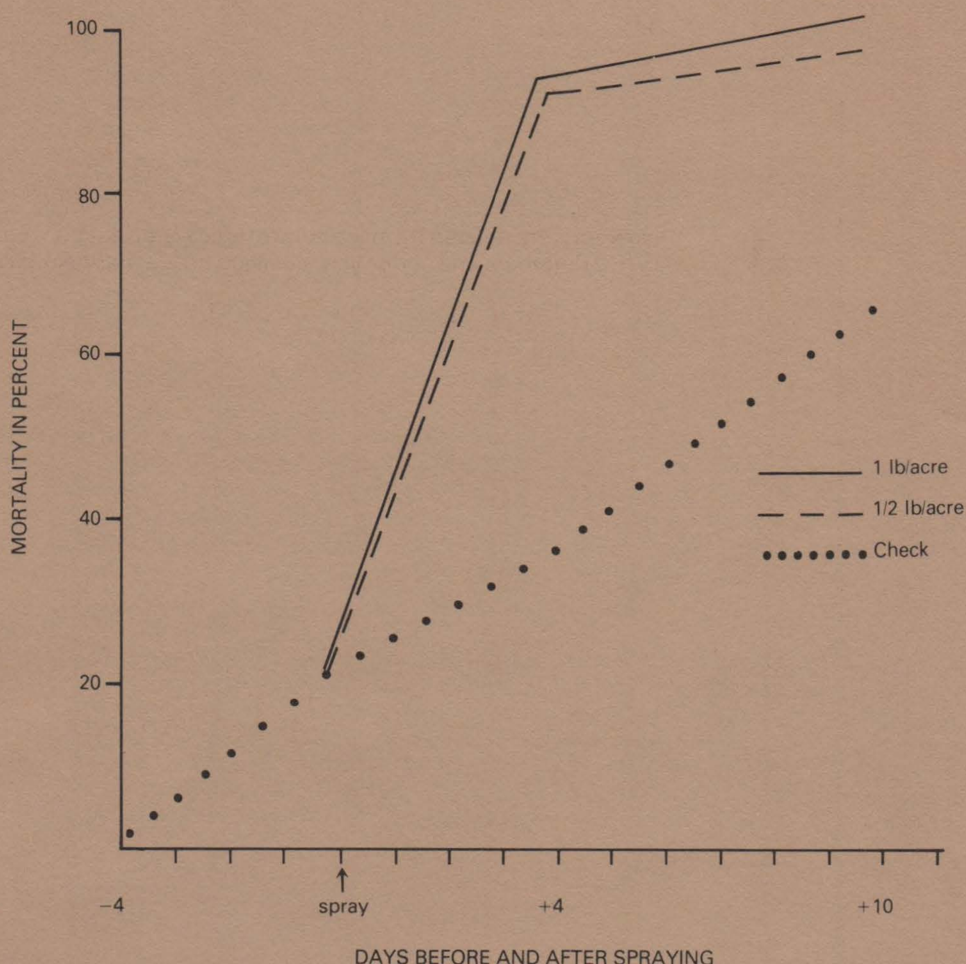

Figure 1. Spruce budworm mortality before and after spraying with Sevin 4 Oil, Minnesota, 1975.

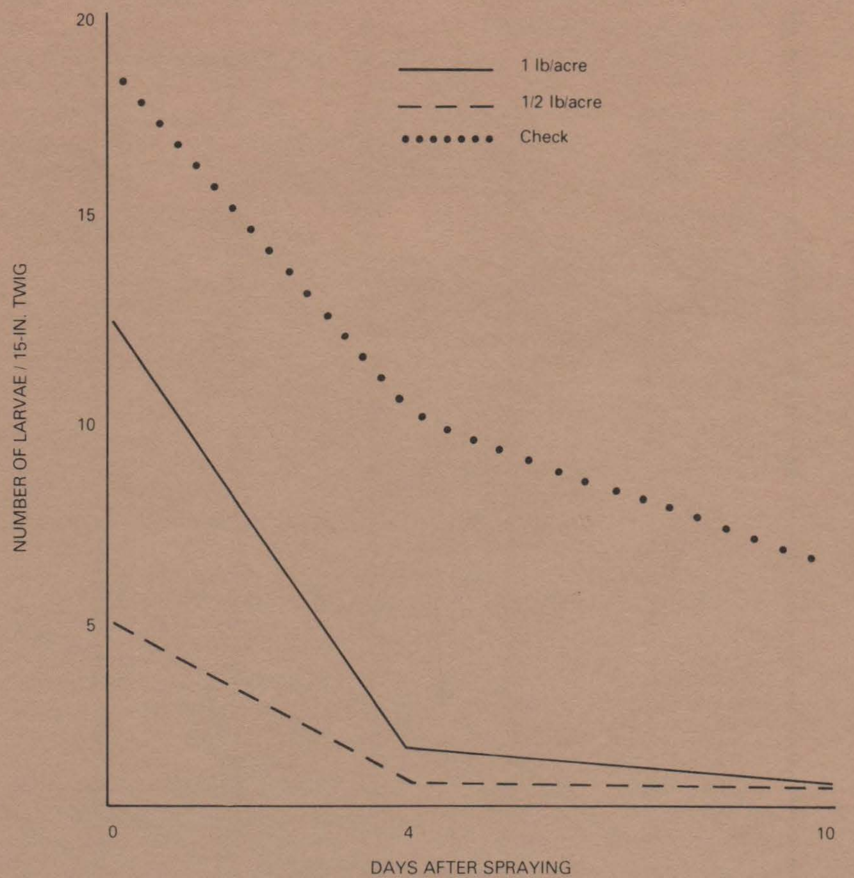

Figure 2. Spruce budworm population decline after spraying with Sevin 4 oil, Minnesota, 1975.

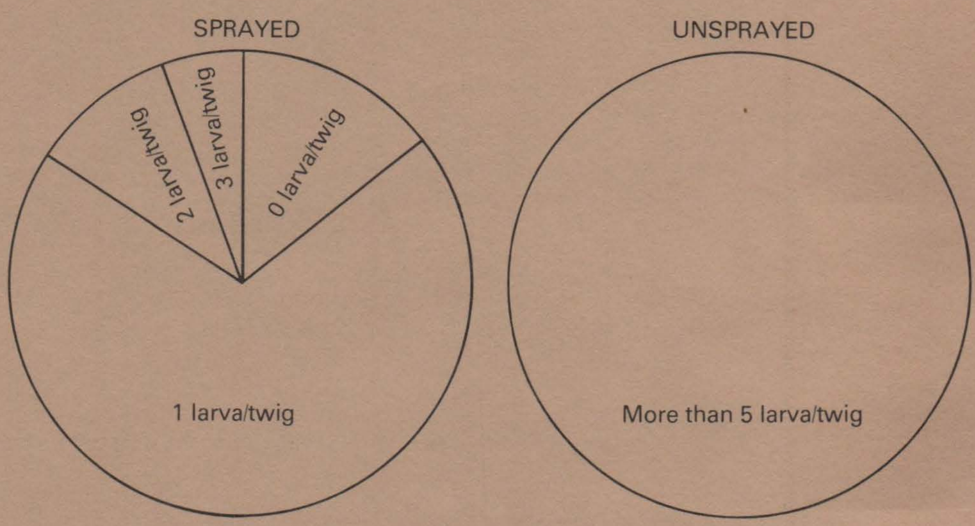

Figure 3. Comparison of expected defoliation between sprayed and unsprayed areas. Proportion of area based on percentages of clusters and remaining foliage based on larval survival 10 days after spraying.

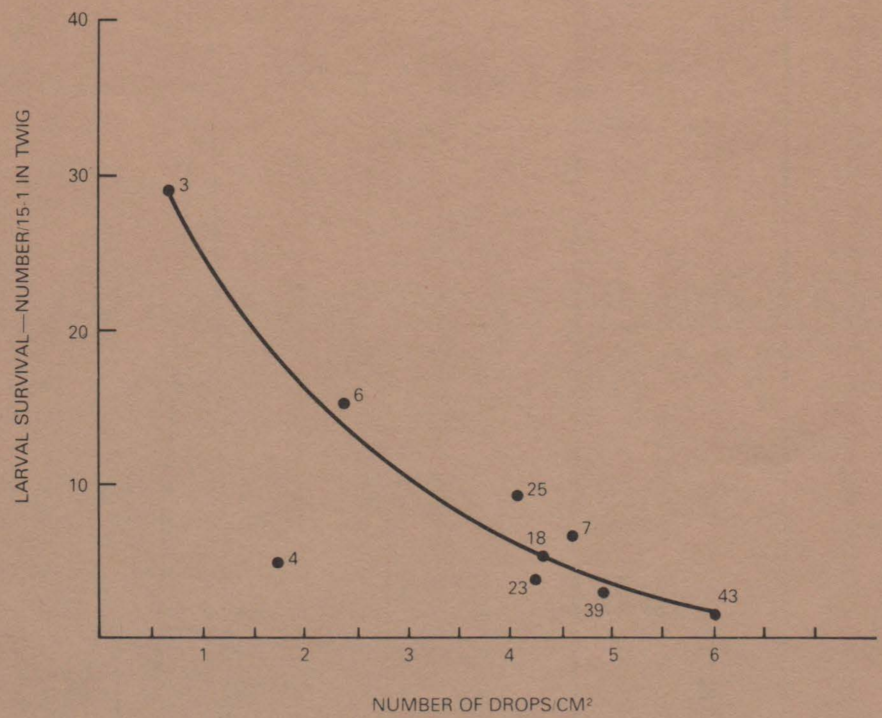

Figure 4. Relationship between Sevin 4 Oil deposit and spruce budworm survival 4 days after spraying, Minnesota, 1975. (Numbers are units of observation).

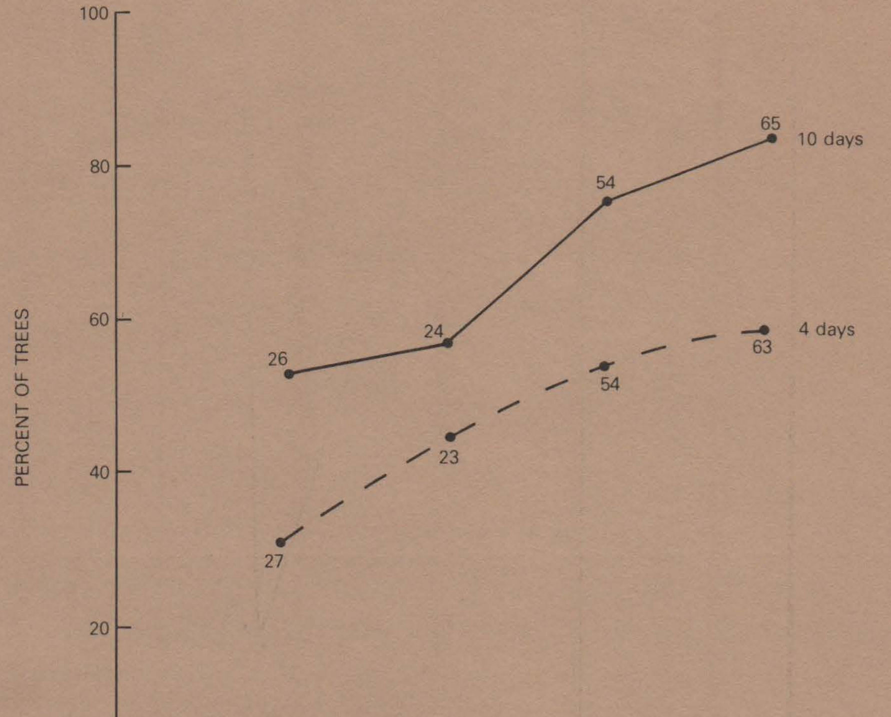

Figure 5. Relationship between Sevin 4 Oil deposit and percent of trees with less than 0.33 larvae per twig survival, Minnesota, 1975. (Numbers are units of observations).

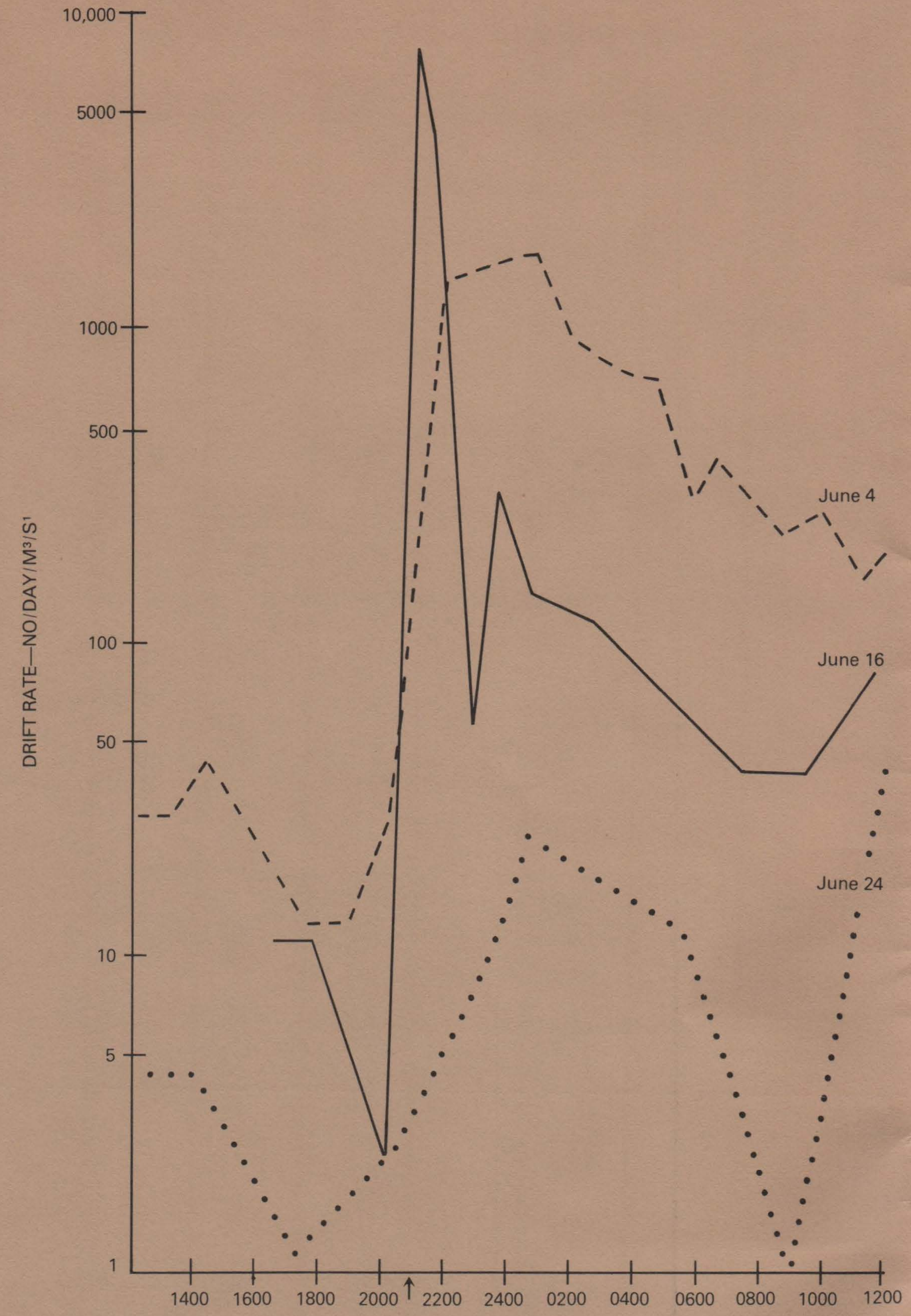

Figure 6. Drift rate of Simuliidae in Civet Creek Tributary before and after spraying with Sevin 4 Oil, Minnesota, 1975. Arrow shows time of spray application.